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SPACE-BASED CHEMICAL LASERS IN STRATEGIC DEFENSE

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Abstract

The Strategic Defense Initiative Organization (SDIO) has made significant progress in developing Space-Based chemical Laser (SBL) technologies and in studying the SBL's global defense capability. In this mission, a constellation of several orbiting laser platforms provides continuous global defense by intercepting threatening missiles in their boost phase, including short range ballistic missiles (SRBMs). An optional smaller constellation provides defense against launches from the low and mid-latitude regions. In addition, SBLs have utility in other important related missions such as surveillance, air defense and discrimination. The hardware necessary to build such a system has been developed to the point where it is mature and ready for demonstration in space. Advances have been made in each of the following major areas of the SBL: laser device; optics/beam control; beam pointing; ATP (acquisition, tracking and pointing); uncooled optics; and laser lethality. Integration of the key laser and beam control technologies is now occurring in the ground-based ALI experiment, and a space demonstration experiment, Star LITE, is in the planning and concept development phase.

Introduction

The collapse of the Soviet Union has diminished the threat of a unilateral and massive first strike against the U.S., but the resulting turmoil and uncertainties in the various republics have increased the risk of a limited, accidental or unauthorized strike. The events in the Middle East before, during and following Desert Storm have highlighted the problem of the spread of missile technology to third world countries along with the technology to build chemical, biological and even nuclear warheads for these weapons.

SDIO is pursuing a wide range of technologies to protect the United States, its troops, friends and allies against such threats. It is pursuing the Space Based chemical Laser (SBL, shown in Figure 1) as a part of its follow-on technology effort. SBL utility and maturity make it a leading candidate for follow-on development and potential deployment. The deployment of SBLs would add an independent defensive tier and a robust, continuous worldwide early boost phase ballistic missile kill capability. The current SBL program is planned through a space demonstration of SBL technology.

An SDIO/TND Workshop on "Directed Energy Systems for Global Defense" was conducted in April and briefed to the Architecture Integration Study (AIS) on June 28 1991, by Col. L. Larson. The workshop concluded that Space-Based Lasers have the broadest potential applicability of any directed energy candidate for global and tactical defense. Figure 2 shows the missions that each DEW candidate is capable of performing. The SBL is the only candidate with capability in all mission areas. This paper will present the analyses and program accomplishments which led to this conclusion.

LAS Threats

A set of Limited Attack Scenario (LAS) threats has been created to give this study a set of hypothetical missile launches in the post-cold-war era. The study used portions of the document "Global Protection Against Limited Strikes (GPALS) Threat Scenario Descriptions 91-1", dated June 28, 1991 to extract its scenarios. The post-2000 threat from this document was adapted as the baseline threat for this Study. (A revised threat document GPALS91-2 was released subsequent to this study. Future work will extract threats from this document.)

The missile launches in the threat occur mostly in the northern hemisphere between the latitudes of 25 - 85 degrees. Figure 3 shows the distribution of launch latitudes for the post-2000 threat. It should be noted that the majority of scenarios, and in particular the theater scenarios, occur at latitudes $\leq$ 55 degrees. The baseline constellation of several platforms can intercept all the threats, regardless of launch latitude. An alternative smaller constellation of platforms would be restricted to missiles launched within the +/- 55 degree zone.

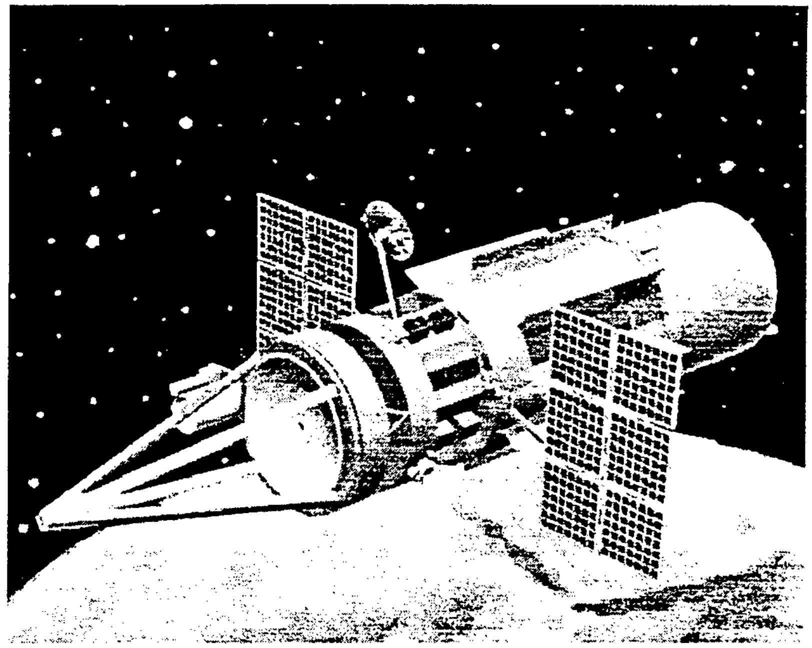


Figure 1 Space-Based Laser Platform Concept

	Space-Based Laser	Air- & Sea-Based Lasers	Pop-Up Particle Beam	Active Sensors Space-Based	Active Sensors Air-Based
Global Boost Phase Intercept	✔				
Theater Boost Phase Intercept	✔	✔			
Interactive Discrimination	✔		✔		
Precision Surveillance Global	✔		✔	✔	
Theater	✔	✔		✔	✔

Figure 2 Directed Energy in Global and Tactical Defense Capability

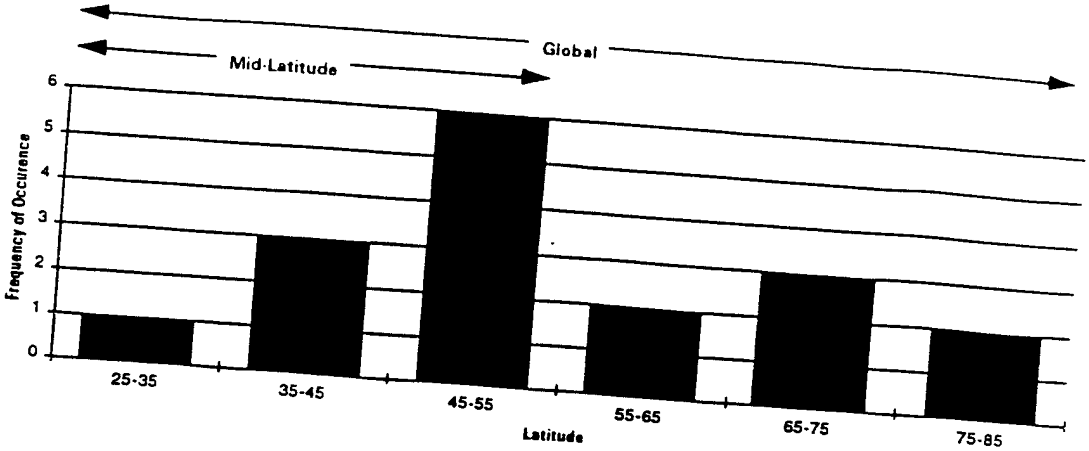


Figure 3 LAS Threat Launch Latitudes

SBL Constellation

An extensive trade study was performed to determine the optimum constellation deployment parameters for the threat scenarios. Two different options were analyzed: 1) worldwide coverage, and 2) mid-latitude coverage option. Figure 4 shows the trade between number of platforms and maximum range, which is influenced by platform brightness and geometric factors such as constellation altitude and the earth's curvature.

The worldwide coverage option, the baseline, has platforms distributed in orbital rings at an approximate altitude of 1500 km and a high orbital inclination. The high orbital inclination is required to intercept ICBMs launched from the northern-most part of Russia and SLBMs launched in bastion in the north of Russia. Robust coverage of the lower inclination threats is provided as well. Dwell times vary, and are directly dependent upon the engagement range from the platform to the target.

The mid-latitude coverage option, the alternate, has fewer platforms in orbital rings at a lower altitude and lower orbital inclination. This constellation is effective against launches within the latitude zone +/- 55 degrees, which contains all of the Third World country launches of interest in the threat document. Coverage of the middle and northern part of Russia is beyond the effective range of this constellation. Other architecture elements such as Brilliant Pebbles (BP) or Ground Based Interceptors (GBI) would be responsible for high latitude and over-the-pole missile launches.

The baseline SBL constellation provides complete global coverage as shown in Figure 5. All areas have at least single coverage, with most areas having between 2 and 4 beams in the battle simultaneously. Even at the poles the engagement range is well within the capability of the platforms to achieve a good kill rate. The mid-latitude constellation provides continuous coverage to +/- 55 degree latitude, with instantaneous coverage reaching into much higher latitudes.

Performance of SBL Constellation

The average kill rates for an SBL platform against the threat missiles vary according to their respective lethality requirements and average target irradiances for the scenarios in which they are used. The kill rate for Scud-class missiles is quite high due to the comparatively low radiant exposure required to destroy it. In general, high kill rates are possible against the metal motor casing missiles, which are more likely to be TBMs, while lower kill rates are obtained for the composite motor casing missiles, which are more likely to be found in the (former) Soviet arsenals.

The engagement range directly affects the irradiance delivered on the target. Shorter engagement ranges, which occur when the SBL is directly above the target, produce the highest irradiance levels on the target, and thus the highest kill rates. The lowest irradiance levels occur when the target is at the edge of the SBL effective range. Figure 6 shows the dependence of irradiance on the engagement range to the target.

The performance of the baseline constellation against the post-2000 threat, summarized in Figure 7, is excellent. The plotted results are for boost phase kills for a stand alone SBL system. Adding midcourse SBL kills and/or other defensive tiers will further add to the robustness of the SBL tier. Global FOR and National Defense the figure shows that for all but scenario six the SBL constellation can achieve

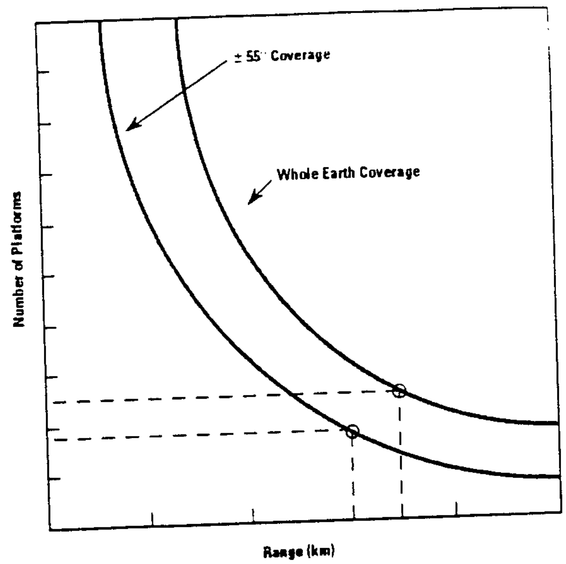


Figure 4 SBL Constellation Parameters

its goal of defeating all missiles from all threats for at least 90% of war start times (constellation/target orientations). The Theater Defense threat scenarios are characterized by simultaneous launches of short range missiles. These cases posed the most serious challenge to the SBL's performance, because of the reduced average boost phase battle time available for each missile. To more thoroughly characterize the capabilities of the SBL constellation, several launch windows were added to the threats. These windows, from 30 sec to 150 sec duration, is the time from launch of the first missile in the salvo to launch of the final missile in the salvo. This situation may also be more realistic than the simultaneous launch scenario because of the difficulty in coordinating a simultaneous salvo. As seen in Figure 7, the SBL performance against the TMD threat is outstanding. Assuming launch windows as low as 30 to 150 seconds allows the SBL to negate the entire TMD threat.

A potential counter-measure to a missile defense system is to depress the apogee of the missiles below the edge of the sensible atmosphere. The feasibility of depressing the trajectories of the threat missiles was investigated by computer analysis. Eight missile types were evaluated, including both theater missiles and strategic missiles. Figure 8 contains a summary of the range capabilities for these missiles.

The nominal trajectory and performance for these missiles was provided with the threat document. The first step in the analysis was to determine the aerodynamic drag coefficients by match-

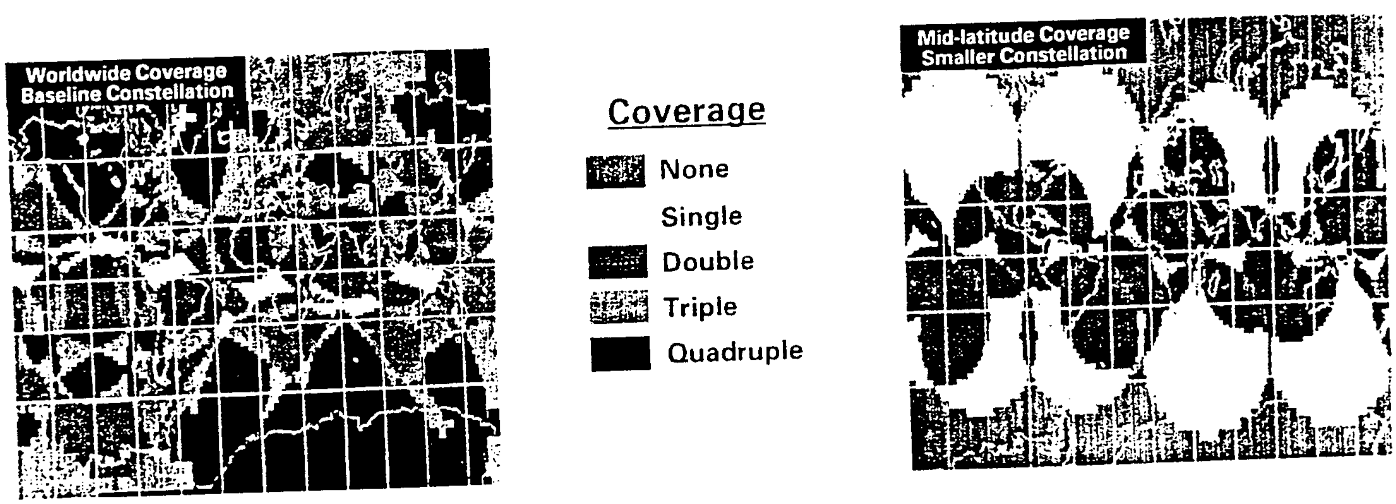


Figure 5 SBL Constellation Coverage

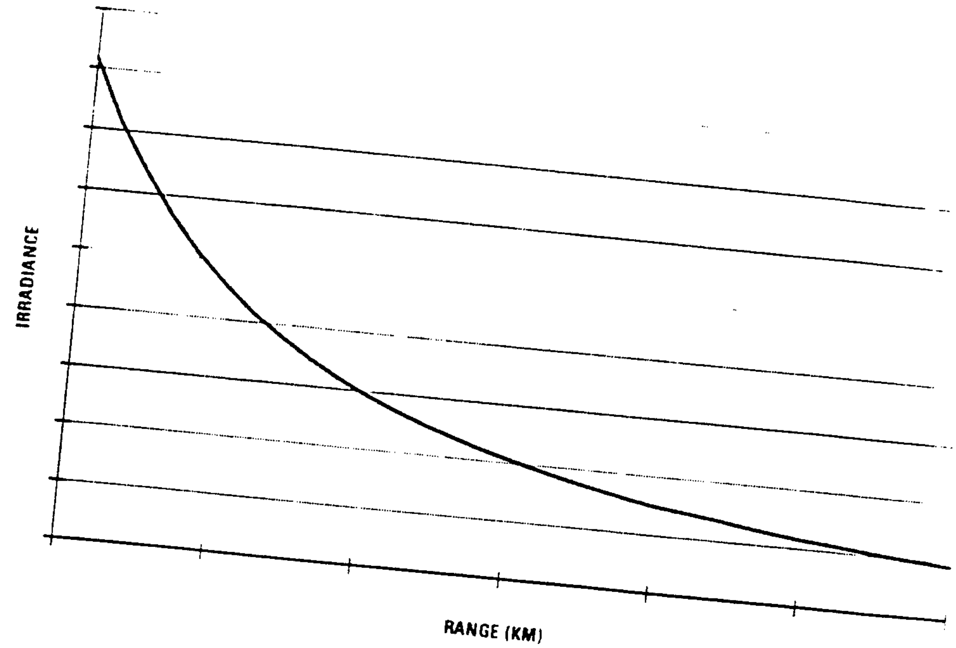


Figure 6 Irradiance on Target

ing the provided trajectories. Once the drag coefficients were found, the depressed trajectories were created by using a gravity gradient maneuver to lower the apogee to between 80 and 100 km. The resulting trajectory and range were then calculated. Only software changes to the missile guidance system would be required to implement the changes; hardware changes would not be required.

Inspection of the chart shows that the range penalty for depressing the trajectory is small for short range missiles, but is larger for longer range missiles (e.g. Threat 8). This makes sense since the longer range missiles nominally have higher apogees and thus are restricted to a much smaller percent of their nominal apogees.

The booster burnout altitude is shown in Figure 9 for the six missile types whose depressed trajectory ranges are shown in Figure 8. The burnout altitudes are not significantly changed by depressing the apogees; they are all above the atmospheric absorbance zone for HF lasers which starts at about 15 km. Therefore, depressing the trajectory of these missiles in no way detracts from the SBL's ability to intercept them in the boost phase. Figure 9 also shows that the baseline HF laser beam is absorbed by atmospheric water vapor in the 5-10 km region, thus posing no threat to ground targets.

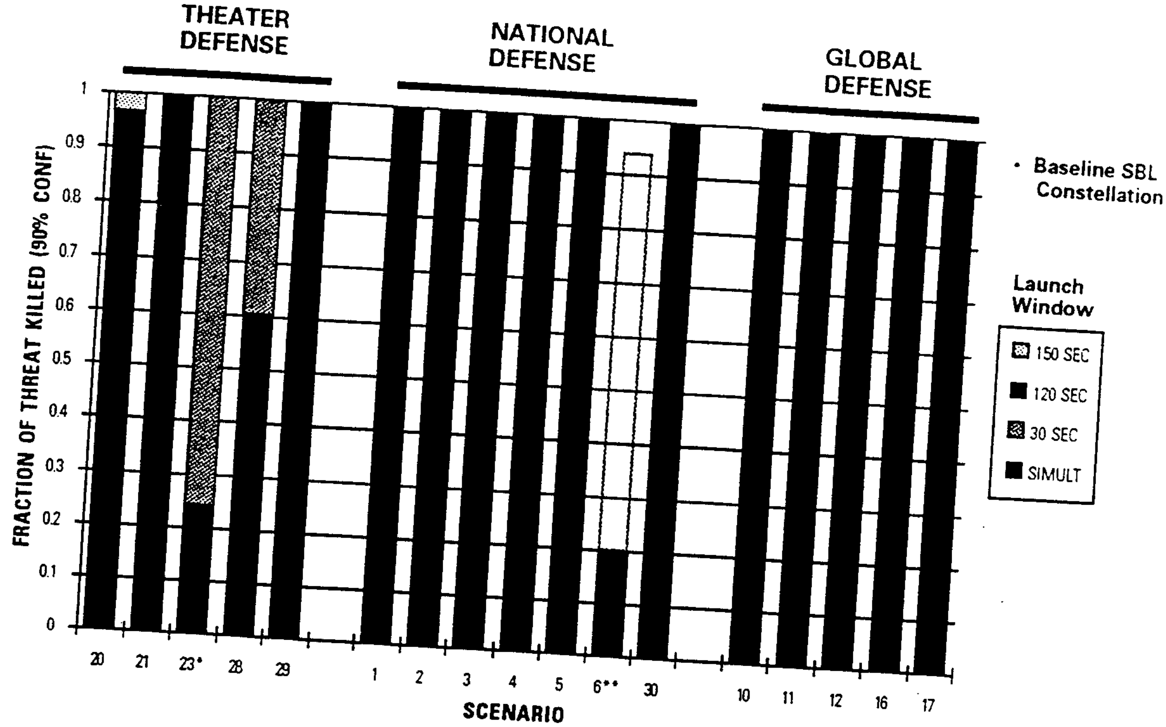
Other Missions

The SBL constellation can perform several other missions in addition to the baseline BMD mission. These ancillary missions include air defense, surveillance, and discrimination, and are shown in Figure 10.

Air-defense - The SBL constellation can engage and destroy both strategic and tactical aircraft. The SBL can engage strategic bombers and cruise missiles at their cruise altitude above the water vapor layer. Flight times are generally long enough to allow the SBL battle manager to shoot only when an SBL is directly overhead, minimizing laser reactant usage. For the case of tactical aircraft a laser wavelength that propagates with good transmission through the atmosphere is required, such as HF overtone. While weather imposed constraints (i.e. cloud cover) will keep the SBL from negating every tactical aircraft on every flight, the SBL can impose unacceptably high losses, quickly grounding virtually any air force. The battle strategy is to engage in a battle of attrition of the enemy aircraft, steadily destroying an ever increasing portion of the enemy's total air force.

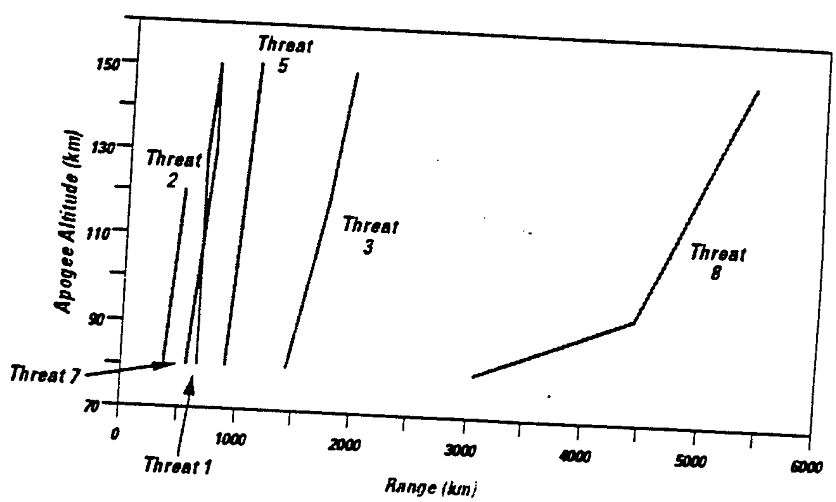
Surveillance - Because of its large, high quality telescope, the SBL platform is capable of resolving distant objects with extraordinary resolution. This capability can be used for ground and space surveillance and/or imaging. If properly cued, it can be used for detection of missile launches and subsequent in-flight tracking. Kill assessment of missiles engaged by the SBL in the boost phase is also possible with the large telescope.

Discrimination - Potentially the most important use of the SBL's optical capability is the discrimination of objects in the mid-course phase of their trajec-



* Scenario 23 assumes 20 sec delay from launch to beam on target, all others 40 seconds.
** Scenario 6 performance can be increased to 95% if a maximum dwell time of 35 seconds is allowed

Figure 7 SBL Constellation Performance



Source: Lockheed Study entitled "Depressed Trajectory Analysis for GPALS" 7 April 1991

Figure 8 Depressed Trajectories for Threat Missiles

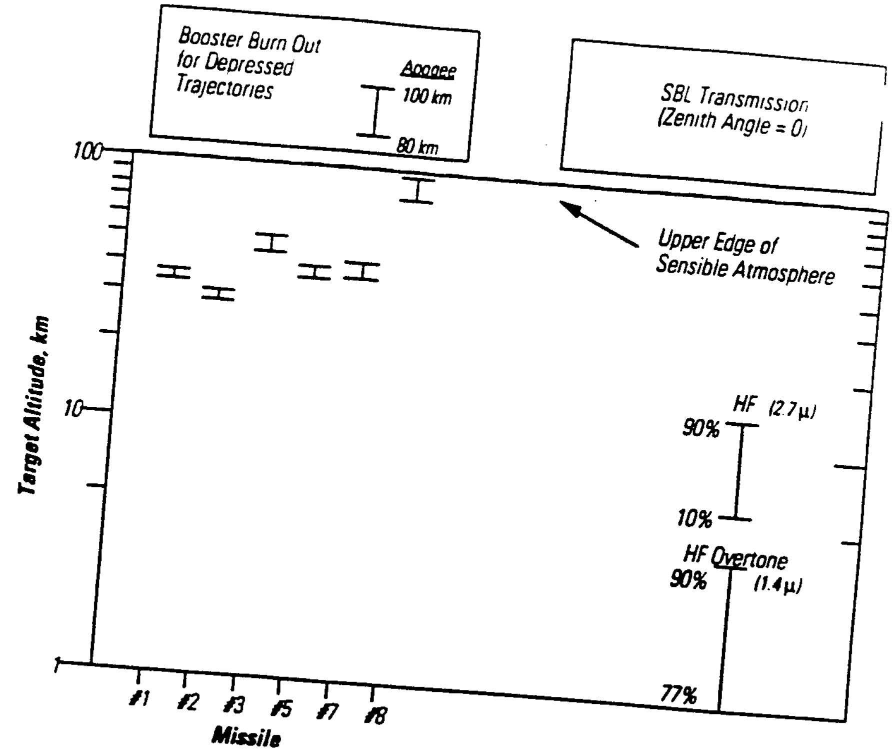


Figure 9 Depressed Trajectory Burn-out

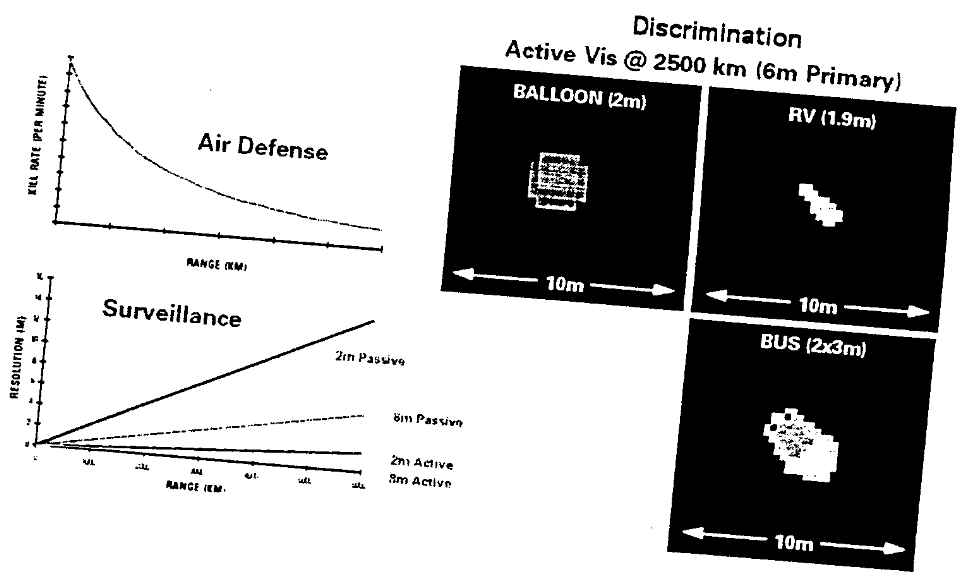


Figure 10 Additional SBL Missions

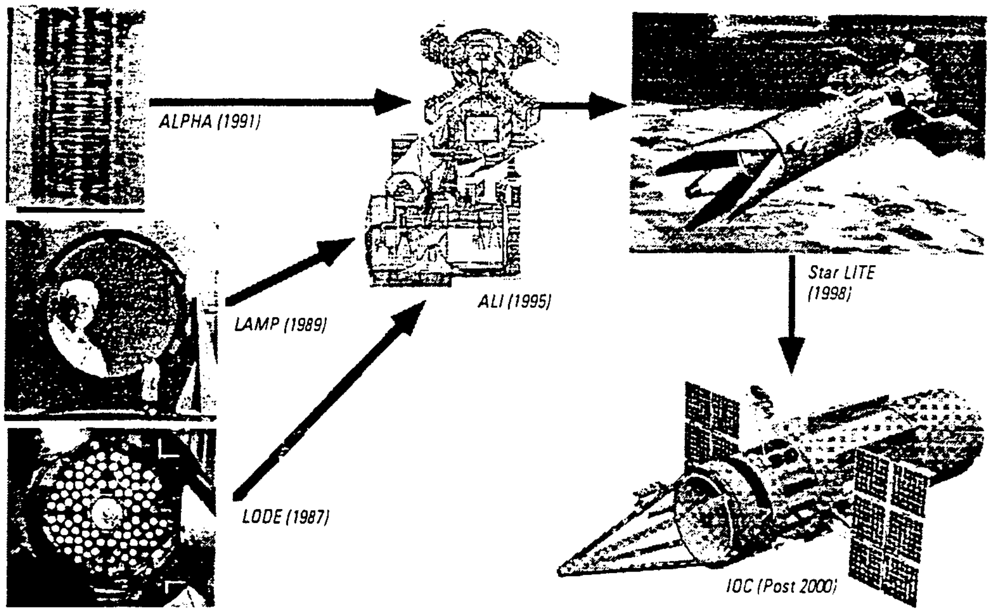


Figure 11 Key SBL Programs

tory, including balloons, RVs, and buses. The high quality focal plane sensor arrays, when used in conjunction with the large high quality beam expander mirror, have the acuity required to distinguish between objects of different shapes and sizes from thousands of kilometers away. This acuity is enhanced if the SBL illuminates the objects with its low power visible illumination laser. In the case of replica decoys, the SBL platform can irradiate all RV-like objects with its high energy beam and discriminate the real RVs from decoys by either observing its resulting velocity change or rise in temperature.

SBL Technology is Mature

The major building blocks for an SBL have all been demonstrated within the last 5 years. Each did so with space compatible designs and hardware that is traceable and scalable to operational requirements. These programs (Alpha, LAMP, LODE) are shown in Figure 11, along with the overall program flow. Generation of megawatt class beam power was repeatedly demonstrated by the Alpha chemical laser in 1990 and 1991. Demonstration of a 4 m primary mirror was accomplished by the LAMP mirror program. LAMP met or exceeded all program requirements including wavefront quality. Overall beam sensing and control techniques were demonstrated on the LODE program in 1987, which addressed correctability of wavefront error and jitter in the beam expander and optical train. All three major experiments will be integrated in a high energy laser experiment called ALI (Alpha-LAMP Integration) in 1995, which will demonstrate the integrated beam generation, control and expansion required for the operational SBL.

Each of these areas appear in the baseline platform concept design, shown in Figure 12. This design is based on over a decade of research, development and testing of the key hardware systems. Some of the important considerations for the platform baseline were: 1) Use of high technical maturity, low risk components, 2) Fit within the envelope of existing or planned launch vehicles, and 3) Have on-orbit servicing and resupply capability. The maturity of the key areas will now be explored in more detail.

Laser Device: The baseline SBL laser device concept uses ALPHA- validated technology to produce HF fundamental laser radiation at around 2.7 microns. This technology is the most advanced high power laser technology, with two high energy (megawatt-class) testbeds (i.e. the MIRACL laser at the White Sands Missile Range (WSMR) and the ALPHA laser at the TRW Capistrano Test Site (CTS)). Use of this advanced technology reduces the risk of a near-to-mid-term technology demonstration. This type of laser was selected for devel-

- **Worldwide coverage with Baseline Constellation**
- **Aperture dia** **8 meters**
- **Run time** **200 sec**
- **Weight** **100,000 lbs**

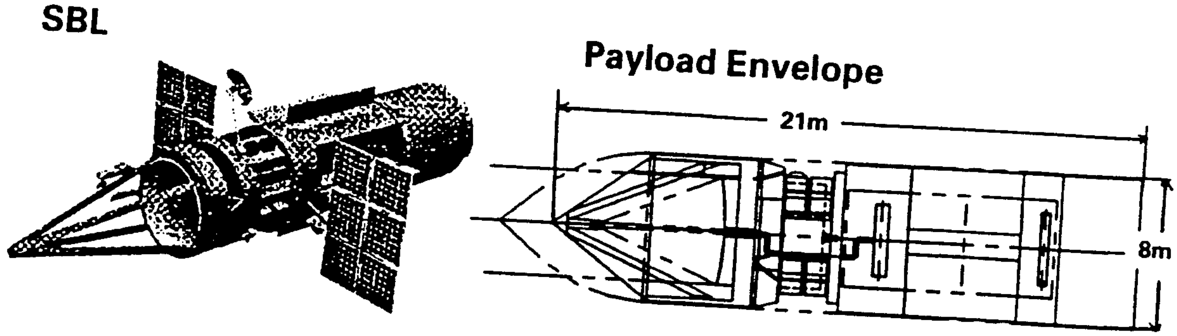


Figure 12 SBL Platform Parameters

opment several years ago because of the exceptional performance projections, as measured by factors such as projected weight and volume per unit brightness.

The operational HF laser device owes its design heritage to the ALPHA laser device, shown in Figure 13. The device uses a cylindrical gain generator assembly (GGA), to provide efficient packaging for space-basing. The gain generator consists of a series of rings which surround the central combustor and form converging/diverging nozzles through which the combustor flow is accelerated to supersonic velocity and mixed with the cavity flow. The cylindrical generator produces an annular gain region of excited HF molecules.

To extract energy from this medium, the ALPHA uses a High Extraction efficiency, Decentered, Annular Ring Resonator (HEX-DARR) configuration for the optical resonator assembly (ORA). The configuration uses cooled annular aspheric optics, fabricated utilizing a single point diamond turning technique.

The overall length of the ORA for the SBL is approximately the same as the overall length of the Alpha ORA. However the length of the annular gain generator inside the ORA is increased by a factor of 3. Such an increase in the length of the ring stack was a capability designed into the ground-based Alpha experiment specifically for scaling to the higher powers more useful for a space experiment. Therefore, very little re-design or re-engineering of the ORA/GGA is required to produce the GPALS laser power requirement.

<u>Optics/Beam Control</u> : The fundamental technology required for the SBL optics and beam control system has been demonstrated on SDIO's LAMP and LODE programs, shown in Figure 14. The LAMP program produced a 4 meter diameter mirror that is scalable to >10 m diameter primary mirror for an SBL. The LAMP mirror is actively controlled with segment and facesheet actuators, and achieves a static figure of lambda/25 RMS. Other new or innovative features include: design using 7-segments; thin facesheet (meniscus); dynamic, high

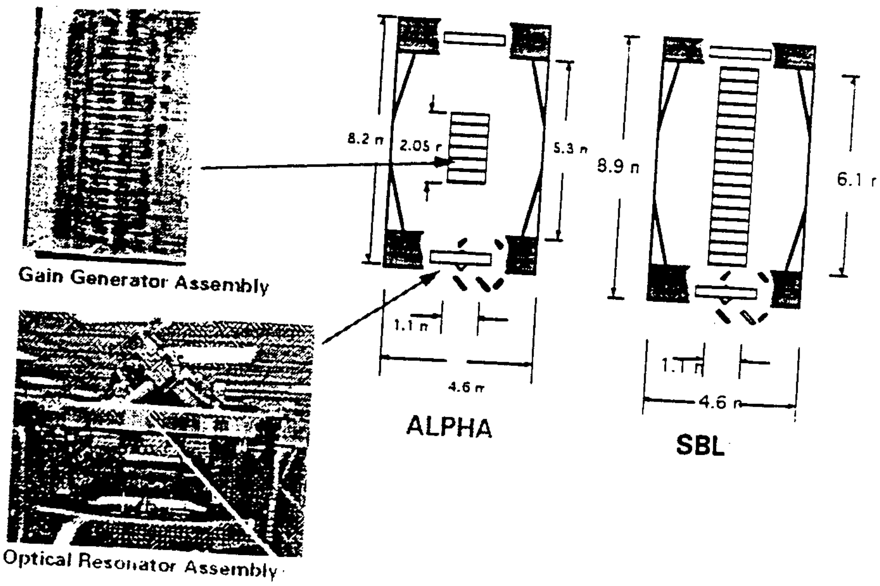


Figure 13 Laser Scaled from ALPHA

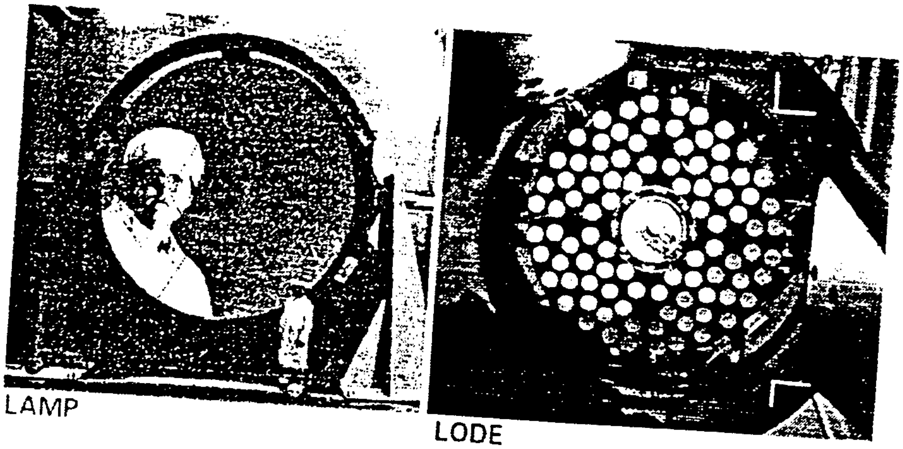
bandwidth actuation with lightweight backup structure; laser distance measuring interferometry (profilometer) for measuring and matching segment radii of curvature very accurately. The LAMP hardware has been completed and tested, meeting or exceeding all specifications.

The Large Optics Demonstration Experiment (LODE) program developed and validated the scalable beam control technologies required for large space-based laser systems using a LAMP-type segmented primary mirror. LODE validated the concepts of sampling and sensing the outgoing beam with Holographic Optical Elements (HOEs) and an outgoing wavefront sensor. Using this information to correct the beam pointing and the beam wavefront errors through a hierarchical control system, the effort culminated in a successful hardware demonstration at Lockheed. During this demonstration, the system was successfully aligned, calibrated, and tested over a broad range of expected jitter and wavefront disturbances. The LODE experiment provided a scalable basis for the ALI experiment, which has further advanced the state of the art in deformable and fast steering mirrors, still using the LODE hierarchical control technology.

Beam Pointing: The capability to accurately point and maintain a laser beam at a distant target was demonstrated by the Relay Mirror Experiment (RME) in 1990, (shown in Figure 15). The RME satellite was launched on a Delta II rocket on February 14, 1990 into a circular orbit of 470 km at an inclination of 43.1 degrees. During the following 14 months several experiments were conducted from two sites on Maui to demonstrate the ability to relay a low power laser beam with unprecedented accuracy up to a satellite and back to a target on the ground. The sequence of the experiment was first to illuminate the satellite with a blue orientation beacon from the Air Force Maui Optical Site (AMOS) followed by a green orientation beacon from the Kihei Test Site also on Maui but about 25 km from AMOS. The satellite then used the orientation beacons to stabilize the relay mirror in a position that bisected the angle between the two orientation beacons. Once the mirror was in place an infrared beacon was directed to the satellite from AMOS and relayed by the mirror on the RME satellite to a target board at Kihei. The results of RME exceeded all project goals.

Acquisition, Tracking and Pointing (ATP):

The ATP subsystem provides the capabilities to acquire and track a target plume, to select an aimpoint on the target hard body, and to direct and maintain the high energy beam on the selected aimpoint. The technology to provide all the ATP



LAMP

LODE

Figure 14 Optics/Beam Control Scalable from LAMP/LODE

functions from target acquisition through aimpoint maintenance are being pursued in a set of technology base activities which include: pointing and controls, fine tracking, rapid retargeting, fire control and ATP integration.

Key components are being fabricated and demonstrated as each technology element matures toward operational system performance levels. Currently an inertial reference unit with 10's of nanoradians precision and accuracy is nearing completion in a joint DARPA/SDIO program, Inertial Pseudo Star Reference Unit (IPSRU), and two contractors will deliver illuminator technology demonstration hardware for long range space applications in the coming year under the Solid State Laser Radar Source (SSLRS) program.

Integrated performance in being pursued in field tests. Figure 16 depicts imagery from a TFE (Tracking Field Experiment) that focused on the tracking of the STARBIRD test booster. This test was conducted from the Atlantic Laser Ground Station (ALGS), Patrick AFB Florida. Algorithms for acquisition, tracking pointing and fire control were integrated and exercised in this test series. This also included testing of hardware such as the Advanced Module Tracker (AMT) developed by the fine tracking technology activities. Figure 16 also illustrates application of the Magic Arrow plume to hard body handover algorithm applied to the TFE

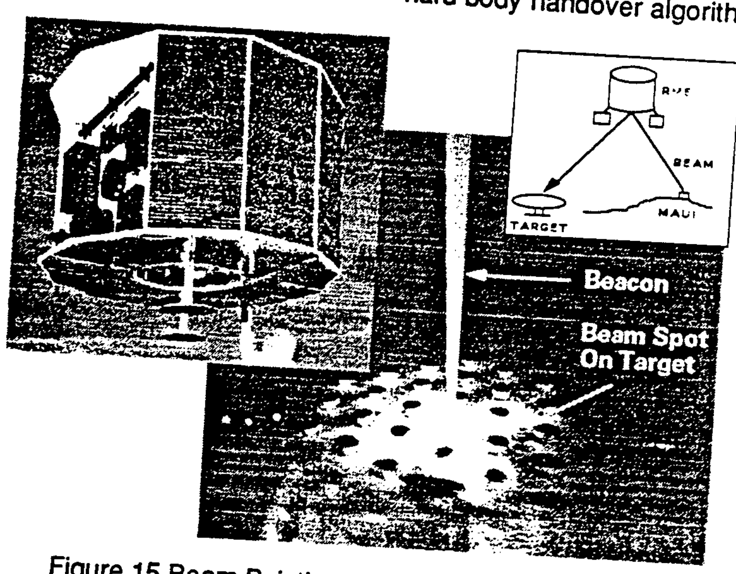


Figure 15 Beam Pointing Demostrated with RME

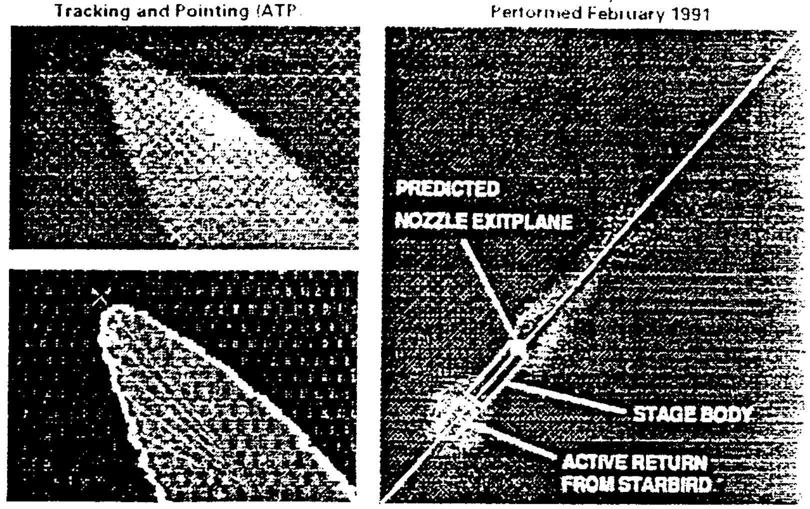


Figure 16 Plume to Hardbody Handover Demostrated

data to locate the hardbody position. It is being developed within the fire control technology base effort. Other TFEs have been conducted at the AMOS facility using the Digital Track which was also developed in the fine tracking technology base program.

The current thrust of the field test programs is to demonstrate the ability to provide all the ATP functions from target acquisition through aimpoint selection and maintenance with realistic boost phase engagements. This will be accomplished with two high altitude balloon borne experiments: HABE and KESTRAL. The KESTRAL effort will provide critical phenomenology and diagnostic data for active and passive operational boosters. This will provide for validation or upgrades of current phenomenology and ATP design codes. HABE will perform integrated ATP engagements of boosters, including acquisition, tracking, aimpoint selection, and stabilization of a simulated high energy laser on the booster aimpoint for scalable engagement scenarios, demonstrating performance in the sub microradian regime. HABE will incorporate many of the advanced technology components such as IPSRU and SSLRS as well as fire control algorithms such as Magic Arrow. The balloon programs will provide several flights per year starting in FY93 to provide conclusive demonstrations of complete ATP capabilities required for space based DEW.

Results from all the ATP activities noted above provide inputs to the ongoing Advanced DEW Acquisition, Pointing and Tracking (ADAPT) program. ADAPT is developing full performance

Typical ALPHA I Inner Cone Hex Plate　　Typical SBL Inner Cone Hex Plate

Figure 17 SBL Etching Has Produced Hex Plates of Unequaled Quality operational system ATP design concepts in its current phase and in later phases will develop a full capability ATP hardware suite for future space based DEW demonstration programs.

SBL Manufacturing Technology: Significant manufacturing advancements have been made in the fabrication of virtually all major SBL components. Advancements realized in the fabrication a second set of Alpha cooled annular optics under the SBLO program serve as an excellent example. These improvements have dramatically cut fabrication times and costs, as described below. First, the original raw material, vacuum arc cast molybdenum, has been replaced by powdered metallurgy molybdenum with equivalent performance, but at a savings of $1.5 million and 8 months. Second, improvements in the etch technique, equipment, and inspections for the coolant channels on the heat exchanger plates have resulted in greatly improved dimensional accuracies of the etch channels, as shown in Figure 17, while reducing the etch time per usable plate from four weeks to less than one week. Third, the number of operations required to braze all the heat exchanger plates to a substrate has been reduced from two brazes to a single braze. These examples of manufacturing process improvements are indicative of the "learning curve" that has been traversed by the SBL program over the last decade of development.

Uncooled Optics : A major breakthrough in optical components for high energy lasers has recently been demonstrated: uncooled optics. These optics eliminate the jitter associated with conventional cooled mirrors, resulting in improved performance, and enabling major cost and weight savings for the SBL platform. The advanced uncooled optics designs, which have been demonstrated at full scale, are based on single crystal silicon substrates with very low absorption (VLA) multi-layer dielectric coatings. As an example of the weight savings from uncooled silicon optics, the uncooled turning flat shown in Figure 18 weighs 17 kg, and replaces a cooled Alpha turning flat which weighs over 180 kg.

Manufacture of the uncooled optics is accomplished by first growing a single crystal silicon substrate. Substrates with diameters as large as 20 inches have been demonstrated. Substrates are then cut from the ingot, ground, etched, polished to very good rms surface roughness, and then coated using conventional evaporative deposition techniques. An Alpha size 17 in diameter uncooled optic can be produced in 6 to 8 weeks, a major reduction from the 8 to 12 months required for a cooled mirror design. Cost of the completed uncooled optic is approximately 15% of the equivalent cooled optic.

Laser Lethality : The ability to destroy targets of interest has been demonstrated since the 1970s using chemical lasers based on the ground. The Mid-InfraRed Advanced Chemical Laser (MIRACL), located at White Sands, New Mexico, is one the most powerful of the ground demonstration lasers. It was used in 1989 to destroy a supersonic Vandal missile in-flight, demonstrating not only the ability of a high energy laser beam to destroy a flying target, but also the capability to track and point at a supersonic target. Another demonstration performed by the MIRACL laser was the 1985 destruction of a Titan second stage, pressurized to simulate flight conditions. This verified the lethality criteria established for this type of missile, and the burst failure mechanism that had been postulated. Both tests are shown in Figure 19.

Launch Vehicle

The National Launch System (NLS), currently under development by NASA, is designed to place heavy payloads into low or mid-earth orbit within the next decade. It would have the capability to lift the SBL platform into the required orbit from the WTR. Payload fairing size is wide enough to accommodate the beam expander diameter of 8 m. A current NLS concept is shown in Figure 20. Several alternatives are available if NASA chooses not to complete the development of the NLS. Examples are the Russian Energia or multiple Titan IV launch vehicles.

Current and Planned Integration Experiments

ALI Experiment : The overall objective of the ALI program is to demonstrate that the Alpha beam projected from a LAMP beam expander can be stabilized and corrected for higher-order aberrations using a beam sampling and control system derived from the LODE beam control architecture. The ALI experiment is designed to correct the output beam to overall wavefront error and jitter values consistent with the requirements of a Space

Figure 18 Uncooled Optic

Based Laser system. A layout of the ALI experiment is shown in Figure 21.

The ALI experiment will address many critical high energy laser functions, including: beam transfer; beam cleanup using the deformable mirror; beam stabilization using a fast steering mirror; beam walk control; beam expansion with a segmented primary mirror; outgoing wavefront sensing; boresighting with an alignment reference beam; system integration; system calibration and remote alignment. Completion of the ALI experiment is planned for 1995.

Star LITE Demonstration: Star LITE is planned as a space based technology demonstration that integrates the technologies required for a space based chemical laser. The experiment is based on the Alpha laser technology, the 4 meter LAMP primary mirror, and the beam control technologies being

MIRACL Chemical Laser at White Sands New Mexico

Inflight destruction of supersonic Vandal missile 1989 demonstrates fielded capability

Destruction of Titan second stage (1985) verifies lethality requirements

Figure 19 Laser Lethality Has Been Demonstrated

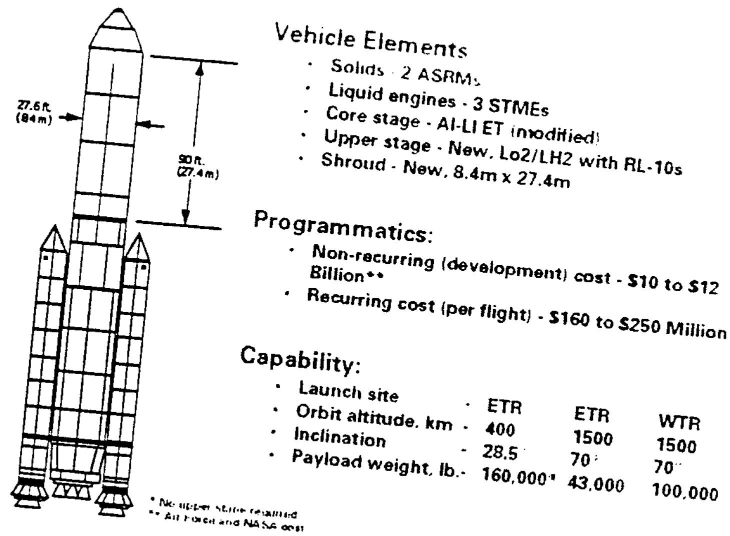


Figure 20 NLS Launch Vehicle

demonstrated in the Alpha LAMP Integration (ALI) program. By incorporating the recent breakthrough of lightweight uncooled optics into the high power beam train, Star LITE is significantly simpler than earlier SBL concepts. For example, the laser payload element produces the same power, but is only one third the weight of a similar laser element using cooled optics. The beam expander, which incorporates a sophisticated telescope, contains less than 50% of the optical elements found in the Hubble Space Telescope. Use of these technology advances combined with a "design-to-cost" philosophy have lead to a Star LITE design with an initial launch capability of 1998. Figure 22 shows a cut away of the vehicle stowed in its pre-launch configuration in a standard Titan IV shroud.

Overall SBL Program Schedule: The overall schedule for SBL development is shown in Figure 23. It shows the progression from ground demonstration (ALI) to space demonstration (Star LITE), to a prototype, to production and deployment of an entry level SBL constellation. Initial deployment could be a small constellation of platforms, which would give good capability over most theaters of interest. The next option is a slightly larger constel-

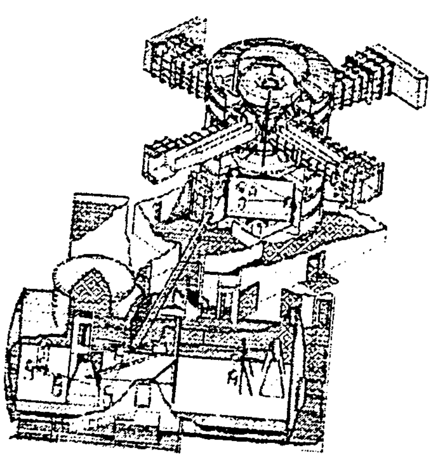
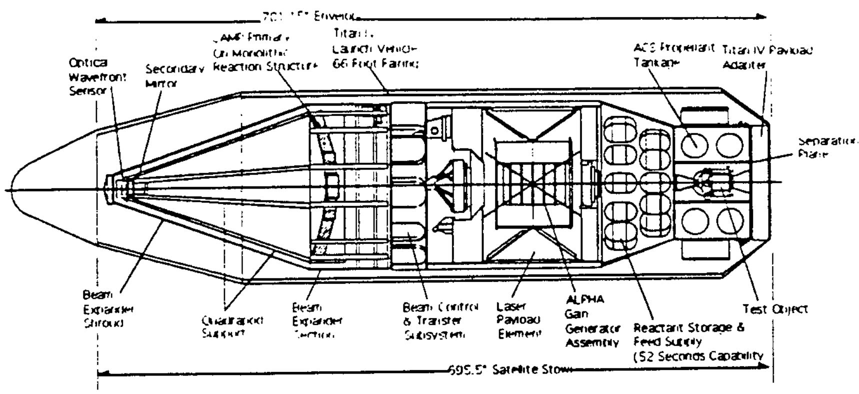


Figure 21 SBL Ground Integration Program (ALI)



LPE	10,412 Lbs	
OPE	12,323	
S/C with Test Objects	12,382	
Subtotal	35,117	
Titan IVA		46,627
Margin (32.7%)	11,510	

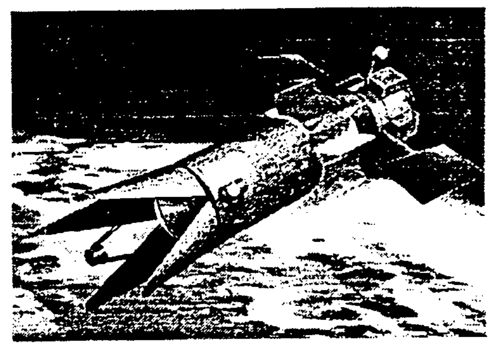


Figure 22 Star LITE Conceptual Design

lation which extends coverage to latitudes high enough to cover launches in the southern part of the former Soviet Union. Finally, a deployment of several more SBLs would give continuous world-wide coverage. Decision points occur at the beginning of each major phase of the program. Once production is commenced, additional SBL platforms can be obtained for a relatively low cost, since the up-front non-recurring costs have already been paid.

Conclusions

Recently completed analyses show that a constellation of several SBL platforms employing near-term chemical laser technology provides extremely effective, continuous world wide defense against limited strike ballistic missile threat scenarios. In addition, the SBL provides highly effective defense against threats stressing to other architectures such as low apogee threats and mid-course threats/counter- measures. The SBL's speed of light propagation to the target provides missile defense architectures with the capability of intercepting missiles while still in the boost phase, effectively countering these stressing threats.

The required laser weapon platform brightness for an effective architecture is achievable within the

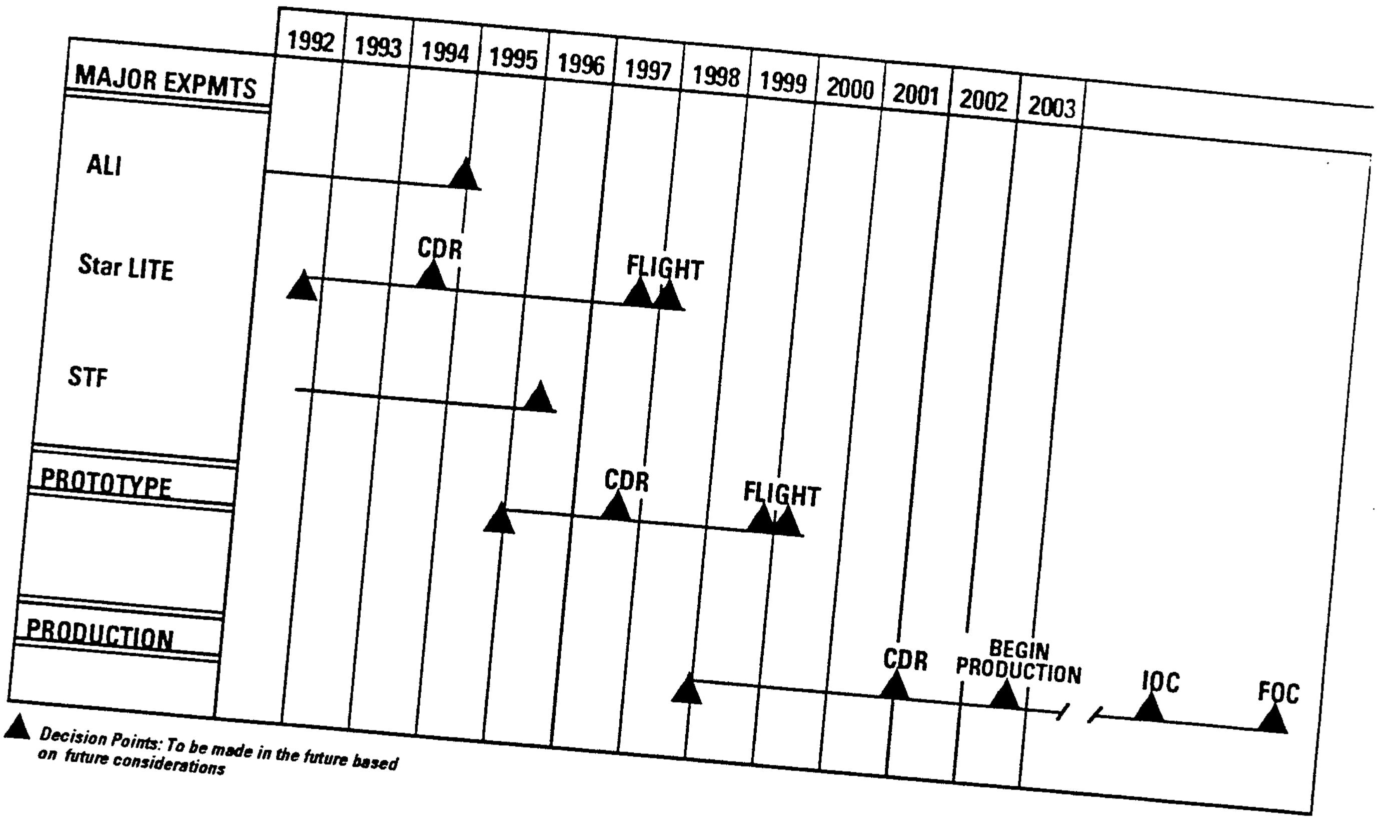


Figure 23 Hypothetical SBL Program Schedule

current state-of-the-art of HF chemical laser technology. The required laser output power can be provided by a gain generator of the same size and materials as the recently demonstrated Alpha device by simply scaling the length from 2 m to 6 m. The 8 m telescope primary mirror is based on the fabrication technology and surface finishing and control techniques successfully demonstrated on the LAMP mirror at the 4 m size. The beam control technology demonstrated on the LODE brassboard will be fully tested at high power in 1995 under the ALI program, an end-to-end, high power test of the Alpha laser integrated with the LAMP mirror.

Finally, HF SBL technology is still rapidly evolving. New short wavelength concepts are being developed along with revolutionary technologies for laser optics and beam control. The pace of these developments insures the continuing relevance of these technologies and systems in future architectures and prevents obsolescence or defeat through countermeasures or technological growth in offensive systems.